REMARKS

Claims 1-34 are currently pending in the application.

Specification

The Examiner objects that the title of the invention is not descriptive. A new title has been supplied that is clearly indicative of the invention to which the claims are directed.

The abstract is corrected to conform to the Examiner's requirements.

Drawings

Corrected drawings are provided as requested by the Examiner.

Rejections Under 35 USC 112

Claim 30 has been amended as requested by the Examiner.

In addition, in claims 5 and 25, "said interference pattern" has been changed to "an interference pattern". In claim 24, "semiconductor" has been deleted since claim 22 gives antecedence for "substrate" alone but not for "semiconductor substrate".

Rejections under 35 USC 102

Claims 1-5, 14, 22, 24-26, 31 and 34 are rejected under 35 USC 102(b) as being clearly anticipated by Kondo (US 4,984,894).

In making his rejection, the Examiner states that Kondo teaches an apparatus for measuring a film thickness comprising a broadband light source for illuminating a film, imaging optics, film, a spectroscopic unit which detects the

intensity of the light reflected from the film and produces a signal defining the intensity variations, and a processor which determines the thickness of the film based on the different frequencies of the signal.

Kondo in fact discusses the determination of a single thin film thickness. In Figure 2B of Kondo, the thickness marked d is the thickness that Kondo manages to determine. The problem that Kondo overcomes is illustrated in Fig. 2A, in which for a fairly simple system a large number of reflections from lower layers are produced and have to be excluded.

The present invention, by contrast, deals with a different situation. It deals with the situation shown in Fig. 1b of the present application. In Fig. 1b a single layer on the wafer substrate has multiple thicknesses as one moves over the substrate, due to the presence of features that are being built into the wafer. The wafer is in fact patterned so that features and therefore thicknesses repeat themselves.

The claims have now been amended to be restricted to the above situation. More particularly the claims now specify that illumination is carried out using a beam of light which is sufficiently wide to cover a region in which features may be repeated. Such wide beam coverage is not disclosed in Kondo which simply discusses constant thicknesses. As a single thickness is required, it is only necessary in Kondo to measure at a single point.

Furthermore, if Kondo were to try and use a wide beam which would cover an area in which the thickness d changed, then it is believed that equation 1 of Kondo would not produce distinct answers but would rather calculate a single average thickness if it would produce any answer at all. The same applies to the second and third type spectrums mentioned in Kondo column 6.

In the present invention by contrast, a wavelength signal is transformed into the frequency domain to give a series of principle frequencies. The principle frequencies correspond to principle thicknesses over the region of the beam. Repeated features on the substrate having identical thicknesses in fact contribute to the same frequencies and do not appear in the resulting signal as separate frequencies as was conventionally believed.

As a result the apparatus and method of the present invention are able for the first time to make real time measurements during a semiconductor manufacturing process. In the prior art a point had to be selected and the semiconductor measured at that point. This meant that the production line had to be stopped as numerous points were measured. The present invention however uses a wide beam and measures a whole patterned area in one go. In fact it is able to do this whilst the semiconductor is spinning. Manufacturing is therefore able to continue unimpeded and yet accurate measurements are available for the semiconductors being formed.

The inventor adds the following comments. The present invention deals with measurement of a patterned area by a wide spot that contains several different thicknesses as shown in Fig 1 below. Patterning of this nature can be found in semiconductors IC's, compact discs etc.

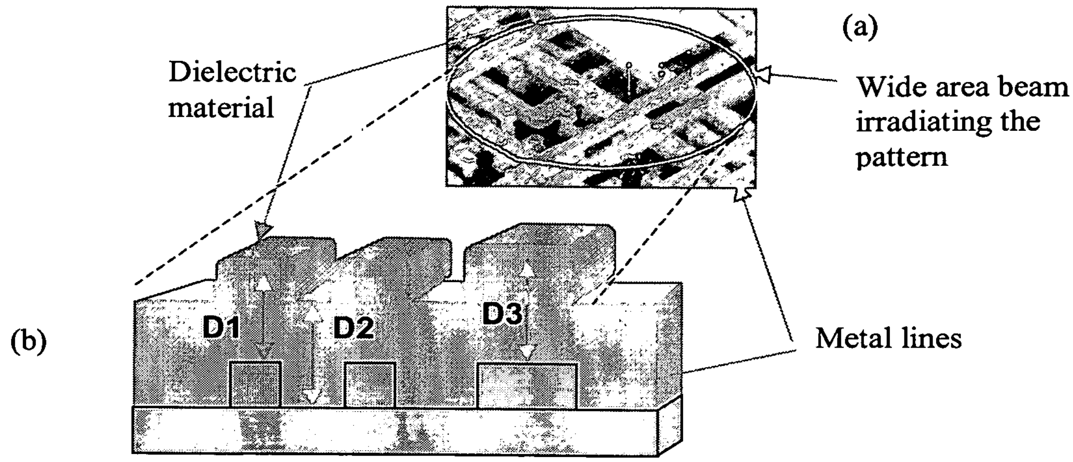

Fig 1. – (a) Top view of dense patterned area of semiconductors chip and (b) schematic presentation of this pattern, as would be seen in cross section

In the example the reflected light from the different thickness arrives to the optical system simultaneously and the reflectance function R(λ) is a combined function of all the different reflectance's functions R(Di, λ) reflected from the different patterns. In practice, once a single measurement is completed the light spot can be moved to the next wide area (fig 2). However the procedure is slow and not suitable for real time measurement during semiconductor manufacture.

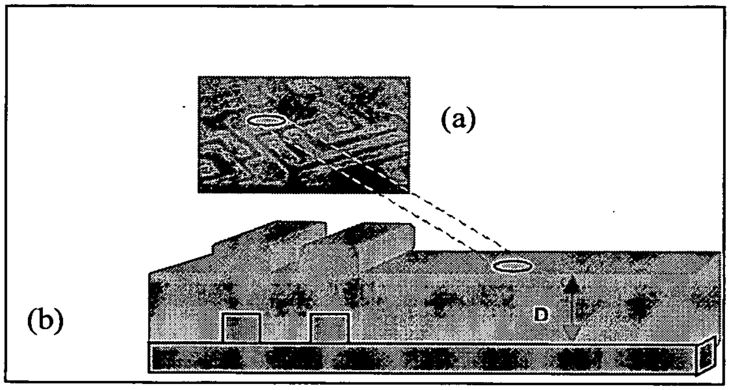

Fig2 – (a) top view of wide, single thickness area. The light spot (blue) is included entirely in it. (b) schematic presentation of this wide area

In the following, we compare between the reflections coming from a multilayered film (fig 3a), single step film (fig3b) and multi-step film (fig 3c) the latter representing patterned structure.

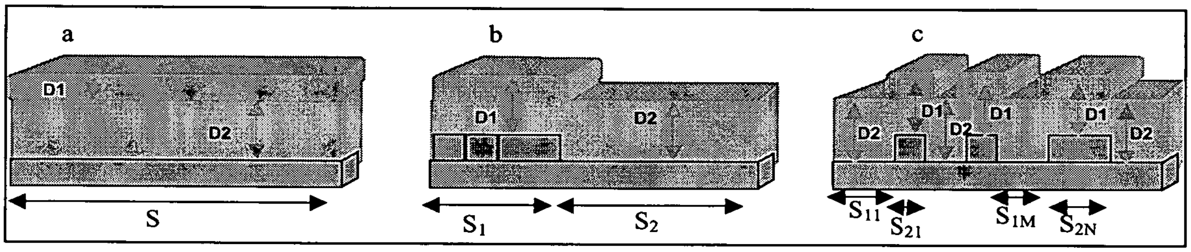

Fig 3: Schematic representation of multilayered film (a), single step film (b) and multi-step patterned film

Fig. 3a is considered in equations 3 and 4 of the detailed description as follows:

Eq 3 – $R_j = \dfrac{r_{j+1} + R_{j-1}e^{-2i\delta j}}{1 + r_{j+1} \cdot R_{j-1}e^{-2i\delta j}}$

Eq. 4- R=

$r_1 + r2\exp(-2i\delta 1) + r3\exp\{(-2i(\delta 2 + \delta 3)\ \} + \cdots + r_{N+1}\ \exp\{(-2i(\delta 1 + \delta 2 + \cdots + \delta_N)\ \}$

In this case the reflecting area S from which the reflected signal is collected by the apparatus is assumed to be identical for the layers 1-N and therefore is not included in the equations.

In the single step example (fig 3b), assuming the irradiated spot is large enough to cover both areas, each of the areas (steps) contributes, to the total reflection, a signal that is a function of δ_i and the area S_i of the respective step.

The total reflection from the stepped layer will be

$$R = S_1R_1 + S_2R_2$$

Where R_1 and R_2 are the reflection per unit area of each of the steps. In the general case with multiple steps in the area measured the total reflection will be

$$R = \sum_l S_l R_l$$

In order to measure a dense patterned area typical to such circumstances as those of a semiconductor IC, a further stage is required, on which Kondo in particular, and other prior art is entirely silent. In the multiple steps of the pattern of fig 3c each stepped features adds its own reflection signal to the total reflection (assuming there is a large enough beam to cover all of the features). At this point an assumption is made

that all identical, that is repeated, features in the pattern (for example all the features above the metal lines) have the same thickness (Di). Thus, the contribution of the reflection of all the identical features can be assumed to be equivalent to the reflection of a single step with the same thickness (Di) and an area Si that is the combined area of all the identical features. If this assumption is true than the reflected signal from the structure in fig 3c is identical to the reflection signal of the structure 3b as long as the combined area

$$\sum S_{j1} = S_1 \text{ and } \sum S_{j2} = S_2$$

Where S_{in} is the area of the feature j of the identical feature group n. In this case, calculating the average thicknesses of each of groups of repeated features is performed analogously to calculating the thicknesses of small numbers of features in a simple pattern, with equivalent thickness and total areas.

This assumption is true only in cases where the formation of the features is performed in a well controlled and spatially uniform process as is typical of semiconductor and CD production processes. That is to say it is true in cases where the regions are truly patterned, but is not true in other fields outside the realm of semiconductors and CDs where thin film measurement is required.

The above assumption is given expression as feature f) of claim 1 and appears in the other independent claims, claims 22 and 34, as well.

In conclusion, the present independent claims, namely claims 1, 22 and 34, define a wide illumination beam which catches repeated features. The repeated features are grouped together under an assumption about uniform thickness so that their measurements can be integrated. The lack of such an assumption prevents the

prior art systems from using a wide beam that illuminates repeated features. The assumption is not hinted at in the prior art.

The remaining claims are believed to be allowable as being dependent on an allowable main claim.

All the matters raised by the Examiner have been dealt with and are believed to have been overcome. No new matter has been added in the present amendments, and the application is therefore believed to be in order for allowance.

Respectfully submitted,

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Date: February 18, 2004

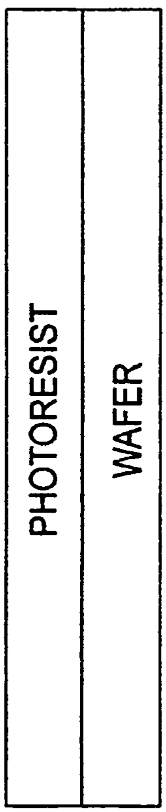

Fig. 1a (PRIOR ART)

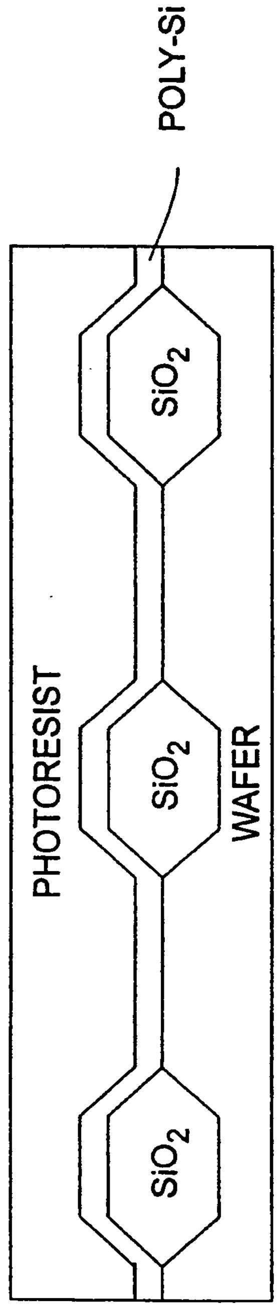

Fig. 1b (PRIOR ART)

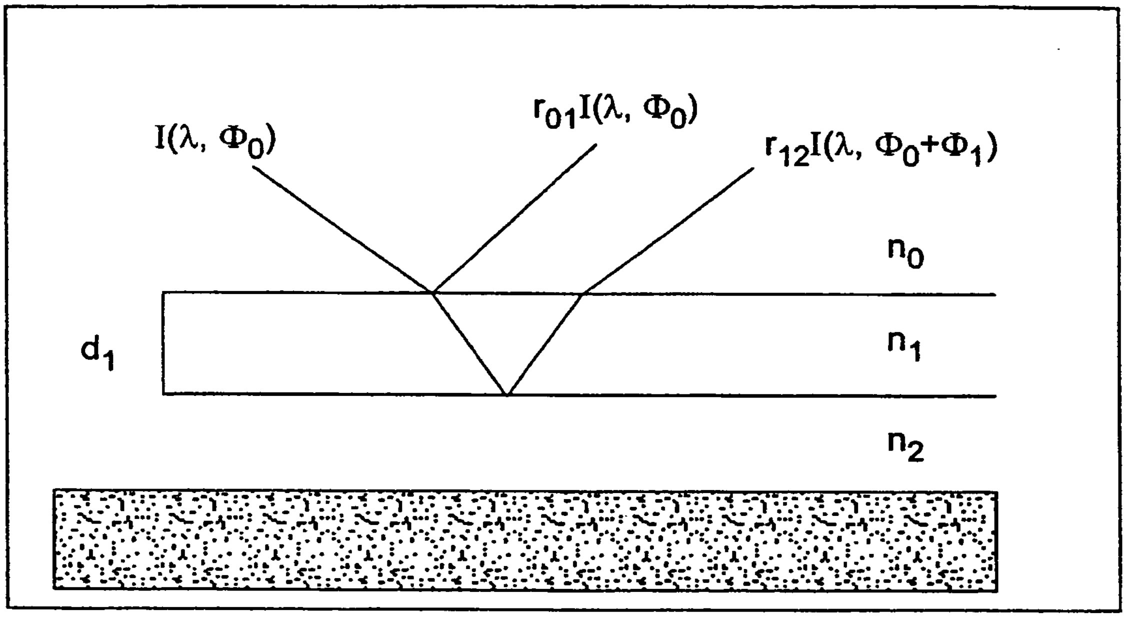

Fig. 2 (PRIOR ART)